Broadband Internet and New Firm Location Decisions in Rural Areas

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Abstract

Improving rural broadband access has been touted as a rural development strategy, but there is limited evidence that broadband service affects rural economic growth. We measure the effect of broadband deployment on locations of new rural firms. Location-specific fixed effects are controlled by a counterfactual baseline that measures how local broadband service in the early 2000s affected local new firm entry in early 1990s before broadband was available anywhere. The change in location choice probability of new firms from the counterfactual baseline to the actual response ten years later is the Difference-in-Differences estimate of the effect of broadband deployment on locations of new firms. We find that broadband availability has a positive and significant effect on location decisions of new firms in rural areas, which is confirmed by a robustness test using ZIP code dummy variables. The broadband effect is largest in more populated rural areas and those adjacent to a metropolitan area, suggesting that broadband effect increases with agglomeration economies.

Key words: Broadband Internet, firm location, rural, agglomeration economies

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Access to broadband Internet is widely presumed to increase economic growth because it lowers firm production costs and broadens the market for firm output.[1] For example, broadband and e-commerce decrease transaction costs, ease coordination and streamline face-to-face communication with nearby upstream suppliers and downstream consumers (Gasper and Glaeser 1998; Borenstein and Saloner 2001; Kinsey 2000; Henderson, Dooley and Akridge 2004; Henderson 2001; and Lamie, Barkley and Markley 2011). Broadband also helps firms reach more distant consumers and suppliers.[2] Broadband may bring footloose service jobs such as call center into rural areas (Stenberg, 2009). Broadband can facilitate better matching between firms and workers (Autor, 2001) and faster learning on market information.[3] These productivity-enhancing factors would raise the location-specific profitability of firms in rural areas with broadband access. Therefore, in competitive markets, firms should have a higher probability of entering markets with higher anticipated profitability.

However, broadband may have negative effects on the rural economy as well (Fox and Porca 2001; Malecki 2003). Just as broadband may allow rural firms to access distant customers, broadband may also allow urban firms to sell more products to rural customers. Broadband may shut down rural branch offices because basic services in branch offices can be replaced by online customer services. Broadband benefits may be largest in more densely populated areas because of complementarities between broadband and agglomeration economies,[4] and because cities have more skilled workers whose skills are enhanced by information technologies (Bresnahan, Brynjolfsson and Hitt 2002; Beaudry, Doms and Lewis 2010). Broadband benefits interacted with agglomeration may attenuate with distance from the urban center (Rosenthal and Strange, 2003, 2008). Thus broadband benefits in rural areas might be limited to those close to urban or metro markets.[5]

The few empirical studies that have explored the effect of broadband on the rural economy have mixed results. Stenberg (2009), Kolko (2012), and Atasoy (2013) report that broadband availability increased rural economic growth. Whitacre, Gallardo and Strover (2014) reported negligible impacts of broadband availability but found that rural areas with higher adoption rates grew faster. Kandilov and Renkow (2010), and Mahasureerachai, Whitacre and Shideler (2010) and Whitacre (2011) did not find significant effects from local broadband service.

One reason that the previous studies may have had conflicting results is their use of aggregate employment or number of establishments as measures of economic outcomes. These measures are dominated by the decisions of firms whose location decisions were unrelated to broadband availability and for whom the cost of relocation would be much larger than any potential return from broadband availability. We focus on newly entering firm location decisions which would be the most sensitive to the presence or absence of local high-speed Internet service.[6] New firm location decisions are predicated on current local infrastructure including whether or not broadband service is available, whereas most existing firms in the location entered before broadband was available in any market.

Another advantage to this study is its ability to control for unobservable firm-specific and location-specific fixed factors that cloud previous measured effects of local broadband availability on local economic growth. Broadband will most likely be installed in areas that are already more profitable for new firm entry, requiring a control for preexisting, location-specific fixed factors that influence profitability even without the broadband availability. As evidence, the correlation between broadband availability in a rural ZIP code in 1999 and new firm entry in the same ZIP code in 1990-1992 before broadband was available anywhere is 0.49.[7] Cleary, broadband availability in a ZIP code is predicated on past conditions for growth in the ZIP code which can lead to spurious correlation between current local broadband availability and contemporaneous local economic growth. However, this correlation between current broadband and past growth allows us to estimate a "counterfactual" broadband effect on location choice probability of new firms before broadband was available anywhere. The change in location choice probability from the counterfactual location choice probability in early 1990s to the location choice probability after broadband started to become available in early 2000s is interpretable as the Difference-In-Differences measure of the broadband effect on location choices of new firms.

We apply our method to data on the universe of new firm start-ups in rural areas of Iowa and North Carolina. We choose rural areas because very rapid deployment of broadband eliminated meaningful variation in broadband availability in urban areas. Broadband deployment started in 1998 and spread quickly in urban areas that had the largest customer base.[8] In urban Iowa and North Carolina, 67% of ZIP codes had at least one provider within a year. In contrast, broadband deployment was considerably slower in rural areas with only 35% of rural ZIP codes having service within one year in Iowa and North Carolina. We find that rural firms are 55% to 98% more likely to locate in ZIP codes with broadband availability. The broadband effect on firm entry is larger in rural areas adjacent to a metropolitan area or with larger population. In a robustness test using ZIP code dummy variables, the effect of broadband on rural firm entry falls to 5%. As we will explain in the paper, this 5% estimate can be viewed as a lower bound estimate of the true broadband effect.

Federal and state governments have invested considerable resources to encourage rural broadband deployment and to reduce the digital divide between urban and rural areas (Gilroy and Kruger 2013; NCSL 2012). Our findings support the view that rural firms are more likely to enter a market with broadband availability. However, our findings do not suggest that universal rural broadband deployment will cause the gap in economic growth between urban and rural areas to close. While broadband availability will increase the likelihood that a firm will locate in a rural area relative to other rural towns lacking broadband, the total number of firms locating in rural towns might not be affected by broadband availability. Moreover, the complementarity between broadband and agglomeration suggests that broadband is most valuable to the rural places close to urban markets or with greater population. The uneven deployment of broadband across rural locations has caused recent rural firm entry to concentrate in a small number of towns with service. The resulting agglomeration of firms in these towns may continue to favor firm location in these relatively few locations, even if broadband access were made universal. Future research will need to investigate whether broadband deployment into rural markets increases the total number of rural firm start-ups.

Literature Review

There is convincing evidence that Information Technology (IT) raises productivity (Cardona, Kretschmer and Strobel, 2013).[9] Productivity gains from IT are also found in developing countries such as Brazil and India (Commander, Harrison and Menezes-Filho, 2011). Firms that adopted IT earlier experienced more rapid productivity gains than similar firms that did not (Dunne et al. 2004). Workers who worked in firms that used information technologies more intensely experienced faster wage growth than comparable workers in firms lacking IT investments (Autor, Katz and Kruger 1998; Acemoglu 2002). These findings are consistent with predictions of endogenous growth theory (Romer, 1986); generation and distribution of information and ideas are important factors in economic growth. IT raises firm productivity because it decreases the cost of communication and information processing, changes business processes and work practices (Brynjolfsson and Hitt, 2000), and creates new products and values through e-commerce (Borenstein and Saloner, 2001). Röller and Waverman (2001) show that the growth effects from IT occur generally across countries, using an analysis of the spread of voice telephony infrastructure.

Numerous studies have shown productivity gains from broadband deployment. Grimes, Ren and Stevens (2012) found that in New Zealand, higher Internet connection speed through broadband raised firm productivity compared to firms with no connection or firms that only had access through dial-up service. Gillett et al. (2006), Shideler, Badasyan and Taylor (2007), Crandall, Lehr and Litan (2007), Koutroumpis (2009), Czernich et al. (2011), Kolko (2012), and Atasoy (2013) all found that broadband deployment is positively associated with economic growth. Ford and Koutsky (2005) found that broadband increases per-capita gross sales. Mack, Anselin and Grubesic (2011) found that the presence of broadband is important to firm location in a subset of service industries such as information, and finance and insurance. The review by Holt and Jamison (2009) confirm these positive broadband impacts from other empirical studies.

A challenge that has plagued all such studies is the endogeneity of broadband deployment. Economic growth in the United States has been concentrated in populous areas (Rosenthal and Strange, 2004), areas that also attracted early broadband deployment. That complicates identification of the unique broadband effect independent of correlated local factors that also affect growth. The review by Holt and Jamison (2009) notes that there are several studies that have found localized economic growth following broadband deployment, but all are subject to skepticism regarding their identifying restrictions. To confront this concern, Kolko (2012) used an instrumental variable approach which used the average slope of local terrain as an instrument for local broadband penetration. The instrument is only valid if local topography does not affect local employment growth, an assumption which may not be valid as he acknowledges, and his instrumental variable estimates of the broadband effect on employment growth are implausibly large.

A second challenge faced by researchers is that the very rapid deployment of broadband eliminated most meaningful variation in access across urban areas. The Federal Communications Commission estimated that by 1999, 59% of ZIP codes representing 91% of the population in the United States had at least one broadband provider (FCC, 2000, p.37), even though broadband deployment began in earnest just one year earlier. As a result, studies focused on the effects of broadband on growth in metropolitan areas have had to rely on variation in the number of providers rather than on the presence or absence of service, even though it is the presence versus absence of broadband that should have the largest impact on growth. Furthermore, changes in the number of broadband providers in metropolitan areas would be due in part to the exit of providers from unprofitable areas as well as added providers to the most rapidly growing areas, adding an additional source of endogeneity in measured local broadband service.

Deployment was much slower in rural than in urban areas. Only 35% of the rural zip codes in Iowa and North Carolina had access by 1999 and only 52% by 2002. In contrast, 67% of urban ZIP codes had access by 1999 and 80% by 2002. If it is the presence or absence of broadband that is most important for local economic growth as opposed to variation in the number of local broadband providers, there will be more fruitful variation to exploit in rural areas.

An additional advantage of studying the impact of broadband on economic development in rural areas is the near one-to-one correspondence between a community and a zip code. This is important because broadband deployment is reported at the zip code level. Consequently, one can tie growth of a distinct zip code area to broadband service provision for the same area. In urban areas where broadband deployment is spread over multiple zip codes, it is more difficult to tie a community to a given zip code area.

There are also reasons why broadband service could be particularly important in rural markets. Agglomeration economies led to the creation of cities (Quigley 1998; Glaeser 2008) and explain the persistent wage gap favoring urban workers over rural workers (Renkow 1996; Mills and Hazarika 2001). The Internet has the potential to change the geography of production. Services may be produced at a distance from the customers of the service. Stages of production may be geographically dispersed and still coordinated. Consequently, proximity between employer and employee or customer and producer may become less important. The possibility of telecommuting also makes it potentially feasible for workers in rural areas to earn back some of the agglomeration surplus that previously only went to metropolitan workers. These possibilities have led some to conjecture that high-speed Internet will create communities of electronically linked rather than spatially linked individuals. Liebowitz (2002) predicted that the Internet will reduce the advantage of "locational monopolies" by which an urban company's proximity to its customers gave it a competitive advantage. If these conjectures are true, there should be substantial benefits for new firms to locate in rural areas that offer broadband service compared to rural areas that do not.

Model

Our model illustrates the role of locational fixed factors on new firm start-ups and offers an avenue by which those fixed factors may be held fixed in empirical applications. To that end, suppose that we have J areas (j=1, 2, …, J) which are defined geographically by ZIP codes. These J areas are distributed across C counties (c=1,…,C). We define t=0 for a period before broadband was available in any of the J areas. Period t=1 designates a time when broadband was available in at least some but not all of the J areas.

Price-taking firms maximize their profit in two stages. In the first stage, firm i calculates its expected profit in each area j at time t. Then the firm chooses the location with maximum profit (π_{it}^{*}) in the second stage:[10]

$$\pi_{it}^{*} \equiv Max_{j}\pi(I_{jt}, z_{jt}, m_{c}, \mu_{j}, p_{t}, w_{jt}, r_{jt})$$

where location j is included in county c. Firm profit (π) is affected by broadband availability (I_{jt}). Local demand shifters, z_{jt}, are measured by the income and education level of residents in the locality and may increase or decrease firm profits. County and state characteristics (m_c) include dummy variables indicating adjacency to a metropolitan area and size of urban population, which may be related to agglomeration economies improving firm productivity. m_c also includes a dummy variable indicating whether the ZIP code is located in North Carolina or Iowa. Firm profit (π) increases in the common market price p_t and location-specific fixed effects (μ_j), and decreases in local wages (w_{jt}) and the rental rate on capital (r_{jt}).

We assume a spatial equilibrium where wages and capital costs are adjusted to local attributes affecting firm productivity (Rosen 1979; Roback 1982). If areas are competitive, firms will expect to make zero economic profits in all areas. If areas that acquire broadband access (I_{jt}=1) increase firms productivity and profitability, the areas will attract additional entry relative to areas that do not have broadband access ($I_{j't}$=0). Entering firms will bid up the input prices for labor and capital until expected profits from additional entry are reduced back to zero. Hence, wages and rents will also be functions of local attributes such as μ_j and I_{jt}. Absent any other sources of productivity differences between the two areas, wages and rents would have been identical. Of course, that is too strong an assumption, and so we allow additional variation in local demand and location-specific labor productivity differences in the form of z_{jt} and m_c.

At time period 1, the linear approximation to our reduced form profit for firms in area j is:

$$\pi^*_{ij1} \equiv \gamma^1_I I_{j1} + \gamma^1_z z_{j1} + \gamma^1_m m_c + \mu_j + \varepsilon_i + \varepsilon_1 + \varepsilon_{j1} \qquad (1)$$

where superscripts on the parameters indicate the time period. The error term ε_i is unobservable firm-specific characteristics. ε_1 is a common factor that affects profitability in all areas such as a country-wide expansion or recession. ε_{j1} reflects transitory factors that the firm observes in assessing its profits in area *j* but that are not observed by the econometrician.

In principle, if we observe the fixed effect μ_j, we can estimate equation (1) directly. However, we do not observe μ_j. If the fixed effect is correlated with broadband availability, which is almost certainly the case, the estimated broadband effect would be biased. To address this issue, we use a counterfactual broadband availability when broadband was not available anywhere. To derive the counterfactual, we begin with the linear approximation to the firm's profit function in area *j* at time period 0:

$$\pi^*_{ij0} \equiv \gamma^0_z z_{j0} + \gamma^0_m m_c + \mu_j + \varepsilon_i + \varepsilon_0 + \varepsilon_{j0} \qquad (2)$$

If we introduce broadband availability counterfactually into equation (2), its estimated coefficient would reflect its correlation with the fixed effect (μ_j). Recall from the introduction that broadband availability in 2000 is highly correlated with new firm entry a decade earlier. That correlation will allow us to estimate the impact of the fixed effects on firm entry in period 0 which will in turn, allow us to take out the fixed effect bias on our estimate of broadband access in period 1.

Consider the projection of the area *j* fixed effect, μ_j, on past and current observed market factors plus the broadband availability indicator in period 1 (I_{j1}, z_{j0}, z_{j1} and m_c):

$$\mu_j \mapsto \theta_I I_{j1} + \theta^0_z z_{j0} + \theta^1_z z_{j1} + \theta_m m_c + \omega_j \qquad (3)$$

where ω_j is an *i.i.d.* error composed of elements of the fixed effect that are uncorrelated with the presence of broadband or of other local factors. Each coefficient in equation (3) reflects its correlation with the fixed effect. Replacing μ_j in equation (1) by equation (3), we obtain:

$$\pi_{ij1}^{*} = (\gamma_I^1 + \theta_I)I_{j1} + \theta_z^0 z_{j0} + (\gamma_z^1 + \theta_z^1)z_{j1} + (\gamma_m^1 + \theta_m)m_c + \varepsilon_i + \varepsilon_1 + \varepsilon_{j1} + \omega_j \qquad (4)$$

Note that θ_I represents the bias in the estimated broadband effect due to the correlation between the ZIP code *j* fixed effect and broadband deployment in ZIP code *j*. Replacing μ_j in equation (2) with equation (3), we get:

$$\pi_{ij0}^{*} = \theta_I I_{j1} + (\gamma_z^0 + \theta_z^0)z_{j0} + \theta_z^1 z_{j1} + (\gamma_m^0 + \theta_m)m_c + \varepsilon_i + \varepsilon_0 + \varepsilon_{j0} + \omega_j \qquad (5)$$

Note that the coefficient on the counterfactual broadband availability I_{j1} in equation (5) is θ_I, the bias in the estimated broadband effect in equation (4). We can tease out the true broadband effect γ_I^1 by merging equation (4) and equation (5) using the Difference-In-Differences:

$$\pi_{ijt}^{*} \equiv (\gamma_I^1 D_{t=1} + \theta_I)I_{j1} + (\gamma_z^0 D_{t=0} + \theta_z^0)z_{j0} + (\gamma_z^1 D_{t=1} + \theta_z^1)z_{j1} + (\gamma_m^t + \theta_m)m_c + \\ \varepsilon_i + \varepsilon_t + \varepsilon_{jt} + \omega_j \qquad (6)$$

where $D_{t=\tau}$ is a dummy variable indicating time period τ.

To estimate equation (6), we use the conditional logit model; each new firm chooses one of the potential *J* areas to enter, based on anticipated profitability. Define the dichotomous variable $E_{ijt} = 1$ if the firm opts to enter area *j* in period *t* and $E_{ijt} = 0$ otherwise. Specifically,

$$E_{ij\mathrm{t}} = 1 \text{ if } (\gamma_I^1 D_{t=1} + \theta_I)\left(I_{j1} - I_{j'1}\right) + (\gamma_z^0 D_{t=0} + \theta_z^0)\left(z_{j0} - z_{j'0}\right) + \\ (\gamma_z^1 D_{t=1} + \theta_z^1)(z_{j1} - z_{j'1}) + (\gamma_m^t + \theta_m)(m_c - m_{c'}) > \zeta_{ijt} \;\; \forall j \neq j' \qquad (7)$$

where $\zeta_{ijt} = \left(\omega_{j'} + \varepsilon_{j't}\right) - (\omega_j + \varepsilon_{jt})$. If the error terms $\omega_j + \varepsilon_{jt}$ and $\omega_j + \varepsilon_{jt}$ follow the type 1 extreme distribution, we can estimate equation (7) using the conditional logit estimation.

Our identification of the true broadband effect on new firm entry relies on the assumed independence between broadband availability (I_{jt}) and the composite error term:

$$\zeta_{ij\mathrm{t}} = (\varepsilon_i + \varepsilon_t + \varepsilon_{j\prime t} + \omega_{j\prime}) - (\varepsilon_i + \varepsilon_t + \varepsilon_{jt} + \omega_j).$$

If this assumption is violated, then estimates of γ_I^1 will be biased. But two of those error terms, the firm-specific effects ε_i and the common economic shock ε_t, are differenced away in the conditional logit estimation as they do not affect relative profitability across areas. The fixed error sources, $\omega_j{}'$ and ω_j, are not correlated with I_{jt} by construction in equation (3).

The only error source that remains as a potential source of bias is the unobserved time-varying effects $\varepsilon_{j\prime t}$ and ε_{jt} which could be correlated with I_{jt}. This would happen, for example, if larger rural towns grow faster than smaller rural towns over time, and broadband deployment is sorted into larger rural towns. This would create a positive correlation between the error term and the observed broadband dummy variable I_{jt}, and that would cause an upward bias in the estimated broadband effect. A more interesting source of bias is that within a county *c*, the deployment of broadband in ZIP code *j* causes firms to enter ZIP code *j* rather than ZIP code *j'* in the same county, even as total entry in the county is unaffected. We will test both of these sources of bias later and find some evidence for the second source of bias.

To mitigate the potential violation of Independence of Irrelevant Alternatives (IIA) assumption underlying the conditional logit model, our specification includes two dummy variables indicating adjacency to a metropolitan area and size of urban population in the county based on Rural-Urban Continuum Codes (RUCC). Our concern is that ZIP codes may be closer substitutes for other ZIP codes located the same distance from a metropolitan area or that have similar population densities. To address that concern, Bartik (1985) introduced a strategy of grouping alternatives by close substitutability. Levinson (1996) applied the strategy to examine how environmental regulations affect the siting of manufacturing establishments.

Our estimation uses six years of new-firm location data: 1990-1992 and 2000-2002. For new firms in 2000-2002, we use one-year lagged broadband availability. We pick one year from 1999-2001 for the counterfactual broadband availability for all new firms in 1990-1992 and 2000-2002 in order to allow for possible reporting error on which ZIP codes had service. As we will show later, the estimated broadband effects are consistent regardless of the years for counterfactual broadband availability.

Data

We define ZIP codes in counties with urban population less than 20,000 as "rural" based on 1993 Rural-Urban Continuum Codes (RUCC). In our empirical model, each new firm chooses one out of 1,015 rural ZIP codes across the two states, which sets J=1,015. These ZIP codes are distributed across 137 rural counties across the two states, which sets C=137.

We apply our empirical model on a sample of 63,341 "commercial" establishments that entered a rural ZIP code in either Iowa or North Carolina during years 1990-1992 and 2000-2002.[11] We restrict the sample to firms with a clear profit motive, and so we exclude non-profit organizations, government agencies and establishments with a public service emphasis such as museums or historical sites. We also remove firms in agriculture and mining because they cannot move freely across locations as their entry decision is affected by site-specific land or resource availability.[12] Firm attributes such as ZIP code-level location and industry are obtained from the National Establishment Time Series (NETS) which provides information on the universe of all firms that opened for business in Iowa and North

Carolina in 1990-1992 or 2000-2002 that had a Duns number.[13] These proprietary data are available at a per state fee, and so our choice of states is based on a budget constraint and a decision to pick two states from different economic regions that had many small counties across a broad continuum of rural and urban settings.

We obtain broadband availability information from Federal Communications Commission (FCC) Form 477. Broadband is a general term for communication technologies enabling "high-speed" data transmission. FCC defines data transmission faster than 200 Kbps in at least one direction "high-speed." Broadband is contrasted with dial-up connection to Internet less than 56 Kbps. In the early 2000s, cable and DSL broadband platforms were popular, but fixed wireless and satellite broadband platforms were rare.[14] The Form 477 reports the number of broadband service providers with subscribers in each ZIP code. We create a broadband availability dummy variable (I_{j1}), which is equal to one if the ZIP code has at least one broadband provider and zero otherwise. We use broadband availability in December, 1999-2001, which are one-year lagged compared to our sample of new firms.

The broadband availability variable (I_{j1}) is subject to measurement errors that may bias our results. Our measured broadband availability only indicates that service is available somewhere in the ZIP code, not that it is available everywhere within the ZIP code. For example, ZIP codes with at least one satellite broadband subscriber would be reported to have broadband although its subscription had very small portion of high-speed lines in early 2000s.[15] This problem is more severe in rural areas because on average, rural ZIP codes span a greater area than urban ZIP codes (Gillett, 2006). This overstatement might lead to underestimation of the broadband effect if many areas are characterized by low broadband penetration rates. Luckily, broadband effects appear at penetration rates as low as 10-20% (Czernich et al. 2011), so we are unlikely to miss effects by overstating rural broadband penetration.

Broadband availability can be understated because providers with less than 250 lines in the state are not required to report to the FCC. It is possible that rural ZIP codes are covered by very small broadband providers who do not report to the FCC. If so, then our control group of ZIP codes lacking broadband service will be contaminated by areas that do in fact have service. Lacking data in these very small providers, we cannot test formally for the importance of the problem beyond noting that this would tend to bias our estimates against finding an impact.

The other included time-varying local attributes (z_{jt}) are education and income levels of residents in the ZIP code. The education variable is measured by people over 25 years old with at least a two-year college degree in that ZIP code, and the income variable is median household income in the ZIP code. Those measures are available from the 1990 and 2000 Census. Given significant travel costs, these variables are expected to reflect local demand for goods and services that are presumed to have an impact on local firm profitability.

County and state characteristics (m_c) consist of three dummy variables indicating whether the county is adjacent to a metropolitan area, whether the county has at least 2,500 urban population, and whether the ZIP code is located in North Carolina rather than in Iowa. The first two variables are based on 1993 Rural Urban Continuum Code (RUCC).[16] While other justifications for including these measures can be advanced, our interest relates to the plausible importance of agglomeration economies as possible complements with or substitutes for broadband availability. Agglomeration economies can improve firm productivity by promoting technology diffusion and innovation (Rosenthal and Strange, 2004). Proximity to upstream suppliers and downstream customers can decrease transaction costs. As opposed to more remote ZIP code areas, these benefits are presumably larger in rural areas adjacent to a metropolitan area or areas with more dense populations (Partridge et al. 2008). However, broadband may alter the importance of proximity which would make its availability even more important in remote counties.

Table 1 presents the 1990 and 2000 average education and income levels for ZIP codes with and without broadband availability in 2000. Recall that broadband was not available in 1990, but even then, education and income are higher in ZIP codes that had the earliest access to broadband service. Education and income rise between 1990 and 2000 in both ZIP code groups but remain significantly larger in ZIP codes with broadband availability. It is apparent why these time varying, location-specific attributes must be incorporated into the analysis as persistent differences in income and education levels are correlated with local broadband availability. Moreover, if firm entry responds to positively to local income and human capital levels, we will have greater firm entry in the broadband ZIP codes due to their advantages in income and education, even if broadband availability has no effect. Our estimates of the impact of broadband availability on new firm entry will be purged of these potentially confounding effects of local education and income on firm entry and early access to high-speed Internet service.

We include 1,015 ZIP Code Tabulation Areas (ZCTA) in our data set. We required a consistent geographical area over the two periods separated by ten years. We assume that the geographical boundaries of ZIP codes are consistent between 1990 and 2000 if the ZIP code numbers are the same over time. We also assume that U.S. Postal Service ZIP codes indicate the same areas as ZCTA codes indicate. Of 1,031 rural ZCTA codes in 2000, 952 were matched to corresponding 1990 Census ZIP codes exactly. The reminder of ZCTA codes was matched with 1990 Census ZIP codes closest to them in terms of distance between geographic coordinates provided by Census Gazetteer Files. 16 ZCTA out of 1,031 were excluded because they did not have any firm entrants in any of the six years (1990-1992 and

2000-2002).

Results

Before turning to the results from our estimation strategy, we illustrate the type of results obtained when endogenous broadband provision is not controlled. These estimates assume that firms are selecting the highest expected profit π^*_{ij1} from all *J* markets in equation (1). These estimates will control for the firm-specific and time-specific errors, ε_i and ε_1, but they will still be biased if the location-specific fixed effect μ_j is correlated with I_{j1}.[17]

The first specification assumes that broadband provision is exogenous, and so only observable variables from period 1 (I_{j1}, z_{j1} and m_c in equation (1)) are included in the estimation. In this case, the fixed effect (μ_j) is an omitted variable in the specification and will be included in the error term. If the fixed effect is positively correlated with broadband availability (I_{j1}), the estimated broadband coefficient will be overestimated. We report the coefficients and then, in brackets, the implied proportional changes in the probability of firm entry relative to not having local broadband service.[18] To put the proportional changes in context, note that the average probability that a firm picks any random zip code is 0.001. The estimated broadband effect in column (1) of table 2 implies that the firm entry probability increases by 280%, an implausibly large impact.

The second specification adds a past number of new firm entrants as a proxy for the location-specific fixed effect μ_j in equation (1).[19] However, an examination of equation (2) shows that the past numbers of firm entrants are also dependent on past values of z_{j0}, m_c, ε_i and ε_0. The past number of new firms is almost certainly correlated with those past values in (1) which would bias the coefficients. As a result, we build in other sources of bias using this strategy. As shown in column (2) of table 2, the proportional change in the probability of firm entry attributed to local broadband availability is 163% which is still implausibly large.[20]

In table 3, we report our Difference-In-Differences impact of broadband availability on location choice probability of new firms. The top half of panel (a) reports the counterfactual coefficients θ_I from equation (7) for local broadband availability in the 1999-2001 period on location choice probability in the 1990-1992 period. The estimates are done three times, one with broadband availability as reported in 1999, the second with broadband availability in 2000 and the third with availability in 2001. Results are not overly sensitive to the timing of broadband service. The bottom half of panel (a) reports γ_I^1: the additional impact of broadband availability in 1999-2001 on firm entry a year later, which should be the true broadband effect controlling for unobservable location-specific fixed effects. The γ_I^1 coefficients are converted into their implied marginal effects on probability of entry which are reported in brackets. In column (1) with counterfactual broadband availability in 1999, the estimate of γ_I^1 is 0.66 with an implied proportional change in probability of firm entry attributed to local broadband equal to 71%. Using our average probability that a randomly chosen firm picks a given location as the baseline, broadband availability increases the probability that a firm chooses that location from 0.0010 to 0.0017. Similar results are found in columns (2) and (3). Our finding that broadband raises new firm entry probability is consistent with Stenberg (2009), Kolko (2012), Atasoy (2013) and Whitacre, Gallardo and Strover (2014), but our estimates of the proportional change in the probability of firm entry due to broadband ranging from 59% - 98% are smaller than the much larger effects found in table 2. While these estimates are more plausible, they still seem too large.

In columns (4) to (6) of panel (a) in table 3, we add interactions between broadband availability (I_{j1}) and two county characteristics: adjacency to a metropolitan area and size of urban population. The top half of panel (a) shows that the correlation between later broadband availability and the location-specific fixed effect is largest in more populated counties that are distant from a metropolitan area. The bottom half of panel (a) shows that the effect of broadband on firm entry is largest in rural counties that are both adjacent to a metropolitan area and that have relatively large urban population. We summarize the implied effect of broadband on probability of firm entry in panel (b) of table 3. These are the average effects across the three sets of estimates in columns (4) to (6) of panel (a). Rural counties adjacent to a metro with an urban population of at least 2,500 (RUCC 6) have the largest proportional gain in probability of firm entry associated with local broadband service at 81%. The smallest gain from local broadband service is in the least populated counties remote from a metro (RUCC 9) with a proportional gain in probability of firm entry of 50%.

Our results suggest that local broadband availability increases new firm entry most in rural counties that are close to areas with urban agglomeration economies and that have greater population. This result is consistent with prior findings that both broadband and agglomeration are complementary with greater concentrations of skills, and so it is not surprising that agglomeration and broadband appear to be complements in production. Our findings are also consistent with the Watson et al. (2005) finding that firms in larger rural towns have greater willingness-to-pay for e-commerce information. It contrasts with Kolko (2012) and Atasoy (2013) who found that local broadband service has the largest impact on economic growth in less densely populated areas. It may be that that broadband service has a different effect on new firm location decisions (our measure) compared to employment growth of incumbent firms (their measure), but it may also be that the bias related to unobserved location specific effects and endogenous placement of broadband service is largest in the most remote markets, a finding consistent with the larger correlation between broadband service in 1999-2001 and new firm location choices in nonadjacent rural counties in 1990-1992 reported in table 3.

We also examine whether the broadband effects differ by industry in table 4 by estimating coefficients associated with interactions between broadband availability (I_{j1}) and firm industry dummy variables. The joint test that the broadband effect is common across industries is reported toward the bottom of table 4 rejects the null hypothesis of a common broadband effect across industries. However, the implied magnitude of the differences in proportional change in the probability of firm entry are very small with no differences larger than 4%. Our finding of homogeneous broadband effects across industries is consistent with Grimes, Ren and Stevens (2012).

The literal interpretation of our finding that broadband availability raises new firm entry probability suggests that broadband presence raises firm profitability. This has to be a transitory effect as other areas for labor and capital should adjust to cause wages and rents to rise in areas where broadband raises productivity, causing profits to equalize across areas with or without broadband access. There is some evidence supportive of those wage and rent effects. Gillette et al. (2006) find that broadband Internet is positively associated with rents. Wages are less sensitive to broadband availability. Forman, Goldfarb and Greenstein (2012) find that high-speed Internet does not affect wage rates except in places with highly educated and more dense urban populations with concentrations of IT-intensive industries. Kolko (2012) finds no effect of broadband on average wages. Because capital is less mobile than labor, these findings suggest that the equalizing factor may come from a bidding up of land prices in areas that have broadband access.

As noted in our derivation of our control for location-specific fixed effects, our estimation relies on the independence between the transitory location specific profitability ε_{jt} and the installation of broadband service I_{jt}. A direct test of this assumption is not possible, but we can vary our empirical realization of ε_{jt} by changing the years of our base period before broadband was deployed. This will add new transitory components due to time-specific errors that affected profitability in the prior period compared to the end-period 2000-

2002. In table 5, we set the base period as 1995-1997 rather than 1990-1992 as in table 3. If transitory factors bias our results, we should get different results than in table 3. However, comparing tables 3 and 5, there are no large discrepancies in sign or magnitude. For our main concern, the range of estimated proportional change in probability of firm entry due to broadband availability is 52% - 94% in table 5 compared to 59% - 98% in table 3.

Our estimation has relied on counterfactual broadband availability to control ZIP code fixed effect (μ_j) in equation (6). We did not include ZIP code dummy variables in order to use both across- and within-ZIP code variations in broadband availability in identifying the broadband effect on entry. That leaves open the possibility that unobserved ZIP code specific factors could bias the results. To test this concern, we include ZIP code dummy variables rather than counterfactual broadband availability. Based on equations (1) and (2), we assume the following profit function of firm *i* in ZIP code *j* in year *t*:

$$\pi_{ijt}^{*} \equiv \beta_I I_{jt-1} + \beta_{Edu} Edu_{jt-1} + \beta_{Inc} Inc_{jt-1} + \omega_j + \varepsilon_i + \varepsilon_t + \varepsilon_{jt} \quad (8)$$

where I_{jt-1} is a broadband availability dummy variable in ZIP code *j* in year *t*-1. Edu_{jt-1} and Inc_{jt-1} denote education and income levels of residents, respectively. ω_j denotes the ZIP-code specific fixed effect. ε_i and ε_t denote unobserved firm-specific characteristics and nationwide economic variation, respectively. ε_{jt} denotes unobserved time-varying factors influencing firm profits. Assuming both that firms choose their locations having the highest profitability, and that ε_{jt} follows the type 1 extreme distribution, we can estimate equation (8) using a conditional logit model. Recall that ε_i and ε_t are differenced away in the conditional logit estimation because they do not affect relative profitability across areas. To handle many ZIP code dummies, we used a Poisson regression with the following mean function:

$$\mathrm{E}(N_{jt}) = \exp(\beta_I I_{jt-1} + \beta_{Edu} Edu_{jt-1} + \beta_{Inc} Inc_{jt-1} + \omega_j + \alpha_t + c)$$

where the dependent variable, N_{jt} denotes the number of new firms in ZIP code j in year t. ω_j and α_t are controlled by a battery of ZIP code and year dummy variables, respectively. c is a constant term. Guimarães, Figueirdo Woodward (2003) showed that estimates are identical between the Poisson regression and the conditional logit estimation.

This estimation relies on only within-ZIP code variation in broadband availability over time. A possible concern is whether the data on broadband availability is reliable. At least some reported changes in availability appear suspect. To illustrate, some ZIP codes had reported broadband availability in 1999 but not in 2000 and 2001, while others reported broadband availability in 1999 and 2001 but not in 2000. Such inconsistent patterns are found in about 7% of our sample ZIP codes between 1999 and 2001.[21] Those patterns are possible even with accurate reporting because providers with less than 250 lines in the state were not required to report their service ZIP codes to the Federal Communications Commission (FCC). It is possible that very small providers served rural areas. If a 1999 provider with 250 lines loses some customers between 1999 and 2001, it will be inaccurately reported as not offering broadband in 2000 and 2001. Measurement error would bias the coefficient on Internet availability toward zero. This problem is more serious with estimators that rely only on within ZIP code variation in broadband availability compared to our previous estimates that used both across- and within-ZIP code variation in broadband. This concern becomes less important over time as increased Internet use lowered the probability of usage falling below 250 lines in ZIP codes with service. The incidence of strange switching in provision diminished by half between 2001 and 2003.

A related concern with reliance on within-ZIP code variation is that we need many observations of switching service within ZIP codes to derive precise estimates of the broadband effect. Thus we estimate broadband effects using our previous 6-year sample

(1990-1992 and 2000-2002) as well as a longer 8-year sample (1990-1992 and 2000-2004) that provides us more switches in service within ZIP codes.

Estimation results are reported in table 6. In column (1), the estimated coefficient for broadband is not statistically different from zero (-0.01). The estimated broadband effect may be biased toward zero because of spurious variation in reported broadband availability in the earliest years of deployment. When we extend the sample to eight years (1990-1992 and 2000-2004), the broadband effect is positive and significant (0.05), which suggests that broadband presence in a rural ZIP code increases new firm entry probability. The implied proportional change in the probability of firm entry due to broadband is 5%, which is much smaller than the implausibly large 55% - 98% implied from the previous estimates using counterfactual broadband availability.

It is important to understand why the estimated broadband effects differ between tables 3 and 6. There are three possible explanations. First, it may be due to sorting of new firms within a county from ZIP codes without to ZIP codes with broadband. Recall that the estimation using counterfactual broadband availability allowed within-county and cross-ZIP code variation in broadband availability to affect the estimated broadband coefficient, but the estimation using ZIP-code dummies did not. The implication is that most of the entry induced by broadband availability may come from firms opting to enter that ZIP code versus other ZIP codes within the same county. In other words, adding broadband to a given rural ZIP code may have a substantial entry effect within that ZIP code but not in the county as a whole.

Second, the gap in estimated broadband effects may occur if ZIP code dummy variables overcorrect the true estimated broadband effects. Correlation or complementarity between unobservable local factors and broadband availability may lead ZIP-code dummy variables to absorb part of true broadband effect, lowering the estimate relative to the true broadband effect. Third, the gap in estimated broadband effects may be due to measurement errors in the reported broadband availability as described above. Given the last two explanations, we suggest that the 5% estimate should be treated as a lower bound for the broadband effect on firm entry although the magnitude seems much more plausible than our upper-bound estimate or those reported in prior studies.

Policy Implication

Federal and state governments have made investments to deploy broadband Internet and close the "digital divide" between urban and rural households. The National Broadband Plan aims to establish universal broadband service by 2020 (FCC, 2010). Rural areas have been underserved by broadband Internet.[22] The federal government has subsidized rural broadband deployment through broadband programs in two federal agencies; the USDA Rural Utilities Service (RUS) and the FCC Universal Service Fund (USF) (Gilroy and Kruger, 2013). RUS mainly supports up-front capital of broadband infrastructure while USF mainly supports operation cost of broadband networks. RUS has several broadband programs such as the Rural Broadband Access Loan and Loan Guarantee Program, and Community Connect Grant Program. USF has programs such as Connect America Fund (formerly, High Cost Program), and Schools and Libraries Program (E-Rate). Money was also allocated to rural broadband under the American Recovery and Reinvestment Act in 2009 (Kruger, 2009). The 2014 Farm Bill contains a Rural Gigabit Network Pilot Program aimed at bringing ultra-high-speed Internet service into rural areas. State governments also have made efforts to promote the roll-out of rural broadband; all 50 states have at least one broadband task force, commission, or a broadband project (NCSL, 2012).

Our results are consistent with the view that government broadband deployment projects in rural areas will increase the likelihood of firm entry in these areas. However, our findings do not necessarily mean that broadband would increase the total number of new firms in rural areas. To establish whether broadband results in a net increase in the number of new firms in rural areas, we would have to have a country-level study. Koutroumpis (2009) and Czernich et al. (2011) found that broadband penetration increased economic growth in the OECD countries, which suggests that broadband has a net positive effect on country-level economic activity.

Our findings do not support the contention that universal rural broadband deployment will lower the gap in urban versus rural firm start-up rates because broadband effect on new firm entry is boosted by the agglomeration of firms. Recall that the broadband availability effect is largest in counties with greater agglomeration or in close proximity to metro areas with agglomeration economies. That suggests that the smallest and most remote rural towns having few local agglomeration economies will get the smallest economic benefits from government broadband deployment projects compared to larger rural counties closer to metropolitan areas. Olfert and Partridge (2010) also emphasized that connective infrastructure between urban and rural areas is one of the best practices for rural development.

Our discussion above is limited only to economic benefits of broadband. Of course, broadband can provide other types of benefits through telemedicine (Whitacre and Brooks, 2013), distance education, broader range of goods and services choices (Mishra, Williams and Detre, 2009), and improvement of community interactions (Stern, Adams and Boase, 2011). However, economic benefits and other types of benefits are related to size of the population served. Given that “the last mile” that delivers high-speed Internet service from a node of the broadband network to an individual customer represents the highest cost for broadband providers and is presumably more costly in remote rural towns, it is not obvious that the benefit from government broadband deployment exceeds the costs in remote rural towns. As Fox and Porca (2001) and Renkow (2007) suggest, selected broadband provision to rural towns where net benefit of broadband is positive may be socially desirable. And those net benefits will be largest in the relatively few rural labor markets that have sufficient population or proximity to an urban market to offer agglomeration economies that complement local broadband.

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[1] For an extensive review on economic impacts of broadband, see Holt and Jamison (2009). For a comprehensive review on economic impacts of information technologies, see Cardona, Kretschmer and Strobel (2013). Vu (2011) found that broadband and Internet access have larger impacts on economic growth than do other information technologies such as personal computers and mobile phones.

[2] Consumers living further from retail stores are likely to spend more over the Internet (Sinai and Waldfogel 2004; Mishra, Williams and Detre 2009).

[3] As suggestive evidence, mobile phone availability improves access to market information and reduces price dispersion in developing countries (Jensen 2007; Aker 2010). Aker and Mbiti (2010) review how mobile phones reduce search costs and improve coordination among firms in Africa.

[4] Sinai and Waldfogel (2004) and Bekkerman and Gilpin (2013) empirically support the complementarity between Internet and cities. They found that residents in larger cities are likely to use more locally accessible information.

[5] In a similar vein, Fox and Porca (2001) argued that the rural areas with better endowments of agglomeration factors complementary to broadband are those adjacent to urban areas rather than more remote rural areas.

[6] Rosenthal and Strange (2003) and Jofre-Monseny, Marín-López and Viladecans-Marsal (2011) advanced similar arguments to justify their focus on new firm location decisions.

[7] This correlation, based on the authors' calculations, is based on non-agricultural and non-mining rural firms in Iowa and North Carolina.

[8] Faulhaber (2002) dates the timing of the earliest available broadband service during 1998 although the legal basis for broadband deployment was set by the 1996 Telecommunications Act.

[9] Jorgenson, Ho and Stiroh (2008) found that IT investments were responsible for 33% of total factor productivity growth and 32% of labor productivity growth between 1959 and 2006. The importance of IT has increased so that by 1995-2000, IT represented 58% of total factor productivity growth and 59% of labor productivity growth.

[10] Empirically, new firm entry is an appropriate indicator for future economic growth. Reviews by Carree and Thurik (2010), and Fritsch (2011) found that new firm entry increases local economic growth.

[11] In our paper, we use 'firm' and 'establishment' interchangeably.

[12] The following industries are excluded: Agriculture (2-digit 2002 NAICS 11), Mining (21), Postal Service (3-digit NAICS 491), Monetary Authorities-Central Bank (521), Nursing and Residential Care Facilities (623), Social Assistance (624), Museums, Historical Sites, and Similar Institutions (712), Religious, Grantmaking, Civic, Professional and Similar Organizations (813), Private Households (814), and Public Administration (2-digit NACIS 92).

[13] Kunkle (2011) discusses advantages of NETS data compared to public data such as the Quarterly Census of Employment and Wages (QCEW). Different from publicly available data based on establishments that file unemployment insurance reports, the NETS data also includes very small establishments such as sole-proprietorships. Excluding establishments having less than 3 employees does not change our results. Estimates are available from the authors upon request.

[14] Broadband service in December 1999 (FCC, 2005) included traditional cable (51.3%), ADSL (Asymmetric Digital Subscriber Line (13.4%), fiber optic cable (11.3%), wireless and satellite (1.8%) and other wirelines (22.1%) with market share in parentheses.

[15] To avoid the overstatement of broadband availability from satellite broadband, Mahasuweerachai, Whitacre and Shideler (2010) used placement of DSL and cable modem platforms. This kind of information may not be appropriate for our study because "technical" broadband availability does not necessarily mean existence of

broadband subscribers. We compared FCC form 477 with the Iowa Utility Board broadband survey, and found that there were many rural ZIP codes where broadband was technically available but did not have any broadband subscribers in 2000 and 2001.

[16] Counties in RUCC 6 and 7 have urban population of 2,500 to 19,999 while those in RUCC 8 and 9 have less than 2,500 urban populations. Counties in RUCC 6 and 8 are adjacent to a metropolitan statistical area.

[17] The number of ZIP codes in this estimation is 1,006 since we include ZIP codes having at least one new firm entry in 2000-2002 into a choice set.

[18] The proportional change in the probability of firm entry with respect to broadband availability is calculated for each firm and each ZIP code and averaged across all firms and ZIP codes. For firm i, ZIP code j, and observed local broadband service level $\{0,1\} \in I_{j1}^{O}$,

$$\frac{\partial P(E_{ij}=1)}{\partial I_{j1}} \cdot \frac{1}{P\left(E_{ij}=1 \middle| I_{j1}^{O}\right)} \approx \frac{P\left(E_{ij}=1 \middle| I_{j1}=1\right) - P\left(E_{ij}=1 \middle| I_{j1}=0\right)}{P\left(E_{ij}=1 \middle| I_{j1}^{O}\right)}$$

where $P\left(E_{ij}=1 \middle| I_{j1}=1\right)$ is the probability that firm *i* chooses ZIP code *j* when broadband is available in that ZIP code, and $P\left(E_{ij}=1 \middle| I_{j1}^{O}\right)$ is the probability that firm *i* chooses ZIP code *j* when broadband service is set at the observed service level.

[19] Similarly, Jofre-Monseny, Marín-López and Viladecans-Marsal (2011) argued that including the past number of existing firms would control for unobserved location-specific fixed effects.

[20] Kolko (2012) also found implausibly large broadband impact on employment growth from his instrumental variable estimation; a unit of increase in broadband increases employment growth by 64 percentage points over 7 years (1999-2006).

[21] That is 76 of 1,015 ZIP codes.

[22] FCC (2012) reports substantial urban-rural broadband digital divide. Also, see Dickes, Lamie and Whitacre (2010) and Whitacre, Gallardo and Strover (2013) for more details.

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Table 1. Education and income by broadband availability in rural Iowa and North Carolina

	1990 Census information			2000 Census information		
	Broadband in 2000: Yes	Broadband in 2000: No	z-stat. (p-value)	Broadband in 2000: Yes	Broadband in 2000: No	z-stat. (p-value)
Education	0.18	0.15	6.3 (<0.01)	0.22	0.18	7.4 (<0.01)
Income	2.35	2.26	3.3 (<0.01)	2.64	2.56	2.7 (<0.01)
# of ZIP codes	423	608	-	423	608	-

Note: Income is reported in 10,000 constant 1989$ units. Z-statistics and p-values are from the Wilcoxon Rank-sum tests of equal distributions in education and income across the two ZIP code groups.

Table 2. Effect of broadband availability on locations of new rural firms: alternative specifications

Dependent variable: ZIP-code choice of new firms in 2000-2002	(1)	(2)
One-year lagged broadband availability	1.68 (0.01)***	1.21 (0.01)***
	[2.80]	[1.63]
# of new firms in 1990-1992 divided by 100	-	1.08 (0.01)***
Education of residents in 2000	3.42 (0.05)***	1.78 (0.06)***
Income of residents in 1999	-0.26 (0.01)***	-0.04 (0.01)***
Adjacent to metro areas (=1)	Yes	Yes
Urban population (2,500+) (=1)	Yes	Yes
Located in North Carolina? (=1)	Yes	Yes
Log-likelihood	-290,844.60	-280,831.54
# of new firms / # of ZIP codes	44,739 / 1,006	

Note: Conditional logit estimation of variations of equation (1). Standard errors are in parentheses. Proportional changes in the probability of firm entry are in the brackets. *** indicates significance at the 1% level.

Table 3. Effect of broadband availability on locations of new rural firms

(a) Estimation results

Dependent variable: ZIP-code choice of new firms in 1990-1992 and 2000-2002		(1) t=1999	(2) t=2000	(3) t=2001	(4) t=1999	(5) t=2000	(6) t=2001
Counterfactual broadband effect (1990 – 1992)	Broadband availability A(t): θ_I	1.28 (0.01)***	1.32 (0.01)***	1.19 (0.01)***	0.79 (0.03)***	1.10 (0.03)***	0.89 (0.03)***
	Broadband availability A(t) x Adjacent to metro areas (=1)	-	-	-	-0.10 (0.02)***	-0.28 (0.03)***	-0.16 (0.03)***
	Broadband availability A(t) x Urban population (2,500+) (=1)	-	-	-	0.67 (0.03)***	0.49 (0.03)***	0.49 (0.03)***
Broadband effect (2000 – 2002)	Broadband availability B: γ_I^1	0.66 (0.02)*** [0.71]	0.55 (0.02)*** [0.59]	0.85 (0.02)*** [0.98]	0.58 (0.03)*** [0.62]	0.25 (0.04)*** [0.25]	0.58 (0.03)*** [0.62]
	Broadband availability B x Adjacent to metro areas (=1)	-	-	-	0.01 (0.03) [0.01]	0.20 (0.03)*** [0.19]	0.05 (0.03)* [0.05]
	Broadband availability B x Urban population (2,500+) (=1)	-	-	-	0.10 (0.04)*** [0.10]	0.25 (0.04)*** [0.25]	0.32 (0.03)*** [0.33]
Log-likelihood		-408,649.15	-409,847.64	-410,957.88	-408,194.32	-409,487.42	-410,653.42
# of new firms / # of ZIP codes		63,341 / 1,015					

Note: Conditional logit estimation based on equation (7). Broadband availability A(t) denotes broadband availability in t for all new firms in 1990-1992 and 2000-2002. Broadband availability B demotes one-year lagged broadband availability for new firms in 2000-2002. Control variables include education and income of residents in 1990 and 2000, and county and state characteristics dummies. Standard errors are in parentheses. Proportional changes in the probability of firm entry are in the brackets. *** and * indicate significance at the 1% and 10% level, respectively.

(b) Proportional changes in location choice probability of new firms by county characteristics by county population and proximity to a metro

Rural Urban Continuum Code (RUCC)	Adjacent to a metro area?	Urban Population	Proportional changes in location choice probability of new firms
6	Yes	2,500 ≤ Population <20,000	0.81
7	No	2,500 ≤ Population <20,000	0.72
8	Yes	Population < 2,500	0.58
9	No	Population < 2,500	0.50

Table 4. Effect of broadband availability on locations of new rural firms by industry

Dependent variable: ZIP-code choice of new firms in 1990-1992 and 2000-2002		(1) t=1999	Effect[a]	(2) t=2000	Effect[a]	(3) t=2001	Effect[a]
Counterfactual broadband effect (1990-1992)	Broadband availability A(t)	Yes		Yes		Yes	
	Broadband availability A(t)×eight industrial dummies	Yes		Yes		Yes	
Broadband effect (2000 – 2002)	Interaction between broadband availability B and:						
	Construction	0.11 (0.07)*	[0.02]	-0.06 (0.07)	[-0.01]	-0.03 (0.06)	[<0.01]
	Manufacturing	-0.11 (0.09)	[<0.01]	-0.22 (0.09)**	[-0.01]	-0.18 (0.08)**	[-0.01]
	Trade, Transportation and Utilities	0.04 (0.06)	[0.01]	0.02 (0.06)	[0.01]	0.01 (0.06)	[<0.01]
	Information	0.09 (0.13)	[<0.01]	0.08 (0.14)	[<0.01]	0.08 (0.12)	[<0.01]
	Financial Activities	0.25 (0.07)***	[0.03]	0.15 (0.08)*	[0.01]	0.21 (0.07)***	[0.02]
	Professional and Business Services	0.10 (0.06)*	[0.03]	-0.18 (0.06)***	[-0.04]	-0.16 (0.06)***	[-0.04]
	Education and Health Services	0.33 (0.09)***	[0.02]	0.18 (0.10)*	[0.01]	0.38 (0.09)***	[0.02]
	Leisure and Hospitality	0 (0.08)	[<0.01]	0.09 (0.08)	[0.01]	0.01 (0.07)	[<0.01]
	Broadband availability B (Reference=Other Services)	0.57 (0.05)***	[0.61]	0.58 (0.05)***	[0.62]	0.87 (0.05)***	[0.99]
Log-likelihood		-408,502.06		-409,717.92		-410,822.06	
Test of the joint hypothesis of equal broadband effects across industries		572.2***		659.0***		569.1***	
# of new firms / # of ZIP codes				63,341 / 1,015			

Note: Broadband availability A(t) demotes broadband availability in t for all new firms in 1990-1992 and 2000-2002. Broadband availability B denotes one-year lagged broadband availability for new firms in 2000-2002. Control variables include education and income of residents in 1990 and 2000, and county and state characteristics dummies. Standard errors are in parentheses. ***, ** and * indicate significance at the 1%, 5%, or 10% level.

[a] Proportional changes in location choice probability of new firms due to local broadband availability are in brackets.

Table 5. Robustness check: Unobservable time-varying location-specific factors

Dependent variable: ZIP-code choice of new firms in 1995-1997 and 2000-2002		(1) t=1999	(2) t=2000	(3) t=2001	(4) t=1999	(5) t=2000	(6) t=2001
Counterfactual broadband effect (1995 – 1997)	Broadband availability A(t): θ_I	1.37 (0.01)***	1.42 (0.01)***	1.29 (0.01)***	0.93 (0.02)***	1.17 (0.03)***	0.93 (0.03)***
	Broadband availability A(t) x Adjacent to metro areas (=1)	-	-	-	-0.07 (0.02)***	-0.27 (0.02)***	-0.13 (0.03)***
	Broadband availability A(t) x Urban population (2,500+) (=1)	-	-	-	0.61 (0.03)***	0.52 (0.03)***	0.55 (0.03)***
Broadband effect (2000 – 2002)	Broadband availability B: γ_I^1	0.59 (0.02)*** [0.64]	0.48 (0.02)*** [0.52]	0.81 (0.01)*** [0.94]	0.47 (0.03)*** [0.50]	0.18 (0.03)*** [0.18]	0.55 (0.03)*** [0.60]
	Broadband availability B x Adjacent to metro areas (=1)	-	-	-	0.02 (0.03) [0.01]	0.21 (0.03)*** [0.11]	0.06 (0.03)* [0.03]
	Broadband availability B x Urban population (2,500+) (=1)	-	-	-	0.14 (0.04)*** [0.11]	0.23 (0.04)*** [0.17]	0.30 (0.03)*** [0.22]
Log-likelihood		-479,454.99	-480,967.02	-482,655.80	-478,993.62	-480,549.52	-482,304.46
# of new firms / # of ZIP codes		74,634 / 1,017					

Note: Broadband availability A(t) denotes broadband availability in t for all new firms in 1990-1992 and 2000-2002. Broadband availability B denotes one-year lagged broadband availability for new firms in 2000-2002. Control variables include education and income of residents in 1990 and 2000, and county and state characteristics dummies. Standard errors are in parentheses. Proportional changes in the probability of firm entry are in the brackets. *** and * indicate significance at the 1% and 10% level, respectively.

Table 6. Conditional logit with ZIP code dummies: Effect of broadband on the number of new rural firms

Dependent variable: # of new firms in …	Six years: 1990-1992 and 2000-2002	Eight years: 1990-1992 and 2000-2004
	(1)	(2)
Broadband availability one-year lagged to years of new firm entry	-0.01 (0.02) [-0.01]	0.05 (0.02)*** [0.05]
Education	0.50 (0.20)**	0.29 (0.20)
Income	-0.11 (0.03)***	-0.03 (0.02)
Log-likelihood	-12,831.08	-14,659.05
# of new firms / # of ZIP codes	63,341 / 1,015	90,280 / 1,022

Standard errors are in parentheses. Proportional changes in the probability of firm entry are in the brackets. ***: p-value<0.01, **: p-value<0.05, *: p-value<0.10. The numbers of ZIP codes vary because ZIP codes having at least one new firm vary depending on sample years. All models include ZIP code dummies.

[Not for publication: Estimation results for footnote 16 on page 13]

Table A1. Effect of broadband availability on locations of new rural firms: Establishments with three or more employees

Dependent variable: ZIP-code choice of new firms in 1990-1992 and 2000-2002		(1) t=1999	(2) t=2000	(3) t=2001	(4) t=1999	(5) t=2000	(6) t=2001
Counterfactual broadband effect (1995-1997)	Broadband availability A(t): θ_I	1.36 (0.02)***	1.38 (0.02)***	1.26 (0.02)***	0.82 (0.04)***	1.11 (0.04)***	0.88 (0.04)***
	Broadband availability A(t) x Adjacent to metro areas	-	-	-	-0.11 (0.04)***	-0.31 (0.04)***	-0.15 (0.04)***
	Broadband availability A(t) x Urban population (2,500+)	-	-	-	0.75 (0.04)***	0.57 (0.05)***	0.59 (0.05)***
Broadband effect (2000-2002)	Broadband availability B: γ_I^1	0.60 (0.02)*** [0.66]	0.54 (0.02)*** [0.59]	0.96 (0.02)*** [1.19]	0.48 (0.05)*** [0.52]	0.15 (0.05)*** [0.15]	0.60 (0.04)*** [0.66]
	Broadband availability B x Adjacent to metro areas	-	-	-	0.09 (0.05)* [0.05]	0.29 (0.05)*** [0.15]	0.12 (0.04)*** [0.06]
	Broadband availability B x Urban population (2,500+)	-	-	-	0.11 (0.05)* [0.08]	0.3 (0.06)*** [0.23]	0.4 (0.05)*** [0.30]
Log-likelihood		-198,024.03	-198,740.70	-199,041.18	-197,760.97	-198,502.29	-198,848.60
# of new firms / # of ZIP codes		30,976 / 991					

Note: Broadband availability A(t) denotes broadband availability in t for all new firms in 1990-1992 and 2000-2002. Broadband availability B denotes one-year lagged broadband availability for new firms in 2000-2002. Control variables include education and income of residents in 1990 and 2000, and county and state characteristics dummies. Standard errors are in parentheses. Proportional changes in the probability of firm entry are in the brackets. *** and * indicate significance at the 1% and 10% level, respectively.